Fermilab

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LOWER ORDER DIPOLE HARMONICS

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Using a Monte-Carlo type calculation we obtain results on the effect of the normal lower order dipole harmonics (b_n, $n = 1 \rightarrow 4$) on the Tevatron lattice.

The input parameters for the calculation are taken from the measured values of the dipole harmonics from magnet 200 on up. We have ignored the systematic terms, using only the standard deviation from the measurements to provide random dipole harmonics. The harmonic coefficients are generated in a Gaussian form and distributed in a random fashion in the dipoles around the ring. No attempt was made at selective ordering of the dipoles to avoid bad magnet groupings. Similarly no acceptance criteria was applied to the magnets, i.e., we accepted the tails of the Gaussian distributions. The machine lattice used in these calculations is the standard Tevatron lattice modified to include two high-beta long straight sections at A and D. The nominal machine tune is set to 19.45. The calculation then proceeds as follows.

The random harmonics are added to the design dipole fields. Using a small off-momentum orbit ($\Delta p/p = 0.05\%$), to avoid the odd harmonics cancelling to the first order, we measure the tune shift produced by the harmonics and bring the machine tune back to 19.45 by applying a suitable correction to the quad bus

current. Next we measure the chromaticity of the machine and correct for it using a 0th harmonic sextupole term generated in the connection coil package. We then turn on the slow extraction quadrupoles and octopoles and use these 39th harmonic driving terms to "tune" extraction so as to remove the effects of the random harmonics.

This procedure was repeated for ten different harmonic distributions and the results are listed in Table 1. One can see tune shifts in the ± 0.01 range as well as changes in the chromaticity of up to ± 5. The strength of the extraction elements stays constant to ~ 25%.

From these results we conclude that the connection coil package as presently conceived will be capable of providing the necessary adjustments to correct the lattice changes introduced by the random fluctuation of the normal lower order dipole field harmonics.

Table 1

				39th Harmonic		
	Tune Shift	Quad Bus Current Change %	Measured Chromaticity	Total Quad. Strength Cosine-like kG - in. at 1 In.	Sine-like	Total Octopole
Nominal	-	-	-22.5	255	-	396
	-0.0018	0.01	-28.2	255	-113	396
	-0.0016	0.008	-20.1	297	127	396
	0.0013	-0.006	-21.0	240	21	334
	0.0034	-0.015	-27.1	226	-	440
	-0.0016	0.01	-25.5	255	42.5	352
	0.0096	-0.05	-17.4	311	99	396
	0.0028	-0.015	-28.9	255	21	396
	-0.0059	0.03	-20.7	255	28	370
	-0.0028	0.015	-21.0	255	21	396
	-0.0033	0.015	-23.5	230	-35	352
			Average Values			
	-	-	-23.4	258	21.1	383

Initial Conditions

$b_1 = 0 \pm 2.0 \times 10^{-4}$ $b_2 = 0 \pm 4.0 \times 10^{-4}$ $b_3 = 0 \pm 1.0 \times 10^{-4}$ $b_4 = 0 \pm 2.0 \times 10^{-4}$